CHAPTER: 7.1

CONCLUSIONS: CHALLENGES, OPPORTUNITIES AND THREATS TO QUINOA IN THE FACE OF GLOBAL CHANGE

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The book entitled *State of the Art of Quinoa in the World 2013* is a joint publication by CIRAD and FAO. It compiles all relevant information on quinoa, generated by the world's foremost researchers, producer organizations, decision-makers and other actors involved with quinoa.

Quinoa has been grown in the Andes for over 5 000 years. During the Spanish Conquest, however, the crop was strongly discouraged, due to its important role in the indigenous culture. Fortunately, in the 1980s, quinoa's potential as a major crop was rediscovered, and there has been a surge in the number of countries growing or experimenting with quinoa. Between the 1980s and the 2000s, the number of quinoa-growing countries increased from just six in the Andean zone to 50 countries around the world with a variety of ecological contexts and climactic conditions. Quinoa's upward momentum is not expected to change – this year, at least another 20 countries have indicated an interest in quinoa cultivation once they have access to phytogenetic resources or improved seeds.

It is no coincidence that quinoa is experiencing this boom. Although many grains and legumes have high protein content, it is today recognized that quinoa has the ideal balance of amino acids essential to humans. What is more, quinoa's high levels of linoleic acid (omega-3) and the fact that most varieties are gluten-free make it an exceptional food. Quinoa's nutritional features mean it has enormous potential in the fight for worldwide food and nutritional security.

Nevertheless, the current heightened interest in quinoa's global expansion is in fact largely due to its resistance to numerous abiotic stresses, particularly drought and salinity. A large proportion of agricultural production around the world depends on the availability of water and irrigation. Intensive use of limited water resources has led to the excessive pumping of groundwater, resulting in saltwater intrusion in coastal areas and soil salinization. In the face of worsening climate conditions due to climate change, a huge area of our planet is threatened by water shortages and soil salinization. These phenomena have intensified in many agricultural zones, particularly in semi-arid regions around the world. Quinoa's high genetic diversity offers a way to address the situation, by adapting to different ecological environments where these limiting factors are present. When evaluating quinoa's adaptation capacity, it is important to bear in mind that quinoa's main production zone worldwide is the southern Altiplano in Bolivia, where average annual rainfall is < 150 mm and frost occurs on > 200 days

per year. The soil is saline, as the region borders on the Uyuni salt flats, and the altitude is about 4 000 m asl. In such extreme conditions, Andean peasants selected quinoa's phytogenetic resources for generations, resulting in a high level of genetic diversity in quinoa landraces.

In order to better appreciate quinoa's global potential, this book presents a series of scientific papers on the state of the art of quinoa in the world. The book is primarily aimed at scientists, students and decision-makers, for whom the information may be relevant and necessary in the implementation of large-scale projects in the fight against hunger. The book is also intended for quinoa producer organizations, which may also benefit from the wide range of material gathered here. The objective of this project is not to provide a comprehensive history of quinoa, but to disseminate the latest information available on this "golden grain" of the Andes. To this end, 22 countries in North and South America, Europe, Africa and Asia contributed to the book. A total of 165 co-authors were convened to work directly on the writing process, and half of them are from the five Andean countries: Argentina, Bolivia, Chile, Ecuador and Peru. The book includes 43 chapters, each of which is dedicated to a specific topic. It is divided into six thematic parts, as outlined below.

The first part is dedicated to the botany and phylogeny of quinoa, and sets out to understand the relative dynamics of its domestication and dissemination leading up to its current area of distribution. The authors provide detailed information on how indigenous communities have preserved quinoa's high levels of biodiversity for centuries. These chapters also present an international perspective on the current risks related to seed flow regulation at various levels. The movement of seeds between human groups contributes to the dynamic evolution of a species by maintaining its capacity to adapt in the face of global changes. In the seven chapters of this first part of the book, the authors share new ideas about quinoa's high levels of diversity, and the innovative genome tools available to characterize the crop's phytogenetic resources.

Rick Jellen and Jeff Maughan, both researchers at Brigham Young University in the United States of America, describe the most recent molecular markers. The range of genetic marker tools developed may be freely accessed by anyone who needs to conduct research on quinoa. A complete review of the state of the conservation of quinoa's genetic resources, coordinated by Wilfredo Rojas of Bolivia, underscores the importance of both *ex situ* quinoa collections found in seed banks in the Andean countries, and the 25 seed banks outside quinoa's zone of origin. This phenomenon is explained by quinoa's current global expansion, with the latest varieties bred for temperate climates developed mainly in Europe and the United States of America. Insofar as the origin of phytogenetic resources and their use to generate innovation, Marco Chevarria-Lazo, a lawyer from Peru, opens a stimulating debate on North-South relations in today's context. He compares the case of quinoa with the expansion of the potato 200 years ago, when there were no national or international seed standards to protect the rights of farmers in the indigenous communities of the Andes. Contributing to this debate, Unai Pascual from the United Kingdom presents the experiment carried out in Peru and Bolivia, on incentive payments (or subsidies) for the *in situ* conservation of quinoa's diversity, exploring the concept of ecosystem services applied to genetic resources in agriculture. The first part of this book also provides a summary of the information available to explain the evolutionary dynamics of the *Chenopodium quinoa* Willd. species, from its centre of origin in relation to its wild relatives. In order to optimize conservation, it is vital that existing phytogenetic resources, both *in situ* and those in gene banks (or *ex situ*), complement each other. There is also an examination of the limitations of regulatory instruments to conserve and protect without impeding innovation.

The second part of this book is an in-depth study of quinoa's biology. Temperature, day length, water availability and sunlight are key factors in quinoa's development. Argentine quinoa specialist, Daniel Bertero, describes the close relationship between quinoa's development and the four environmental components controlling plant growth.

Quinoa's agricultural potential for dissemination and expansion to other regions of the world is linked to its great capacity to adapt in the face of climate change and its effects. Stefania Biondi, a biologist at the *Università di Bologna* (University of Bologna) in Italy, describes quinoa's tolerance and adaptation to saline conditions. Andres Zurita-Silva, of the Chilean *Instituto Nacional Agropecuario* (National Agricultural Institute) addresses in detail quinoa's response and adaptation to drought. Ale-

jandro Bonifacio from Bolivia and Luz Gómez from Peru provide a historical review of quinoa breeding programmes, aimed at maintaining drought and salinity tolerance, while also increasing seed yield, improving disease and pest resistance and maintaining kernel quality. This second part also presents a comprehensive view of agronomic and ecological issues, and each chapter includes a review of scientific literature on a specific biotic or abiotic factor, with the goal of better understanding how quinoa's adaptation to a broad range of ecological contexts in the Andes can be extrapolated to establish the crop in other regions around the world.

The third part of this book begins by describing various processes carried out to eliminate saponins from quinoa seeds to make them fit for human consumption. Jacopo Troisi, an Italian chemist, explains that the saponins present in quinoa may have value as by-products for medicinal or cosmetic purposes, or as natural cleaners. In consideration of the high nutritional content of quinoa seeds currently used for human consumption, Antonio Blanco, an agronomist from Bolivia who works at the *Universidad Católica del Maule* (Catholic University of Maule) in Chile, demonstrates quinoa's value as animal feed. He includes a description of the different parts of the plant that can be used for various kinds of animals in marginal livestock-producing zones. Francisco Fuentes, a Chilean geneticist working at the University of New Jersey in the United States of America, reviews the latest research on quinoa's biological properties as an anti-oxidant, anti-inflammatory or anticarcinogen. Victor Zevallos, a gastro-enterologist at King's College in London, describes quinoa's potential role in a gluten-free diet for patients suffering from coeliac disease. Chapters in the third part of this book unveil quinoa's wide range of potential uses, among which human consumption is simply the most visible.

Given the diversification of and potential for quinoa-based products, it is necessary to examine how legal instruments on food and agriculture are adapted to consider quinoa crops and quinoa-based products.

The fourth part of this book reviews domestic and international quinoa markets. The current Chilean Minister of Agriculture, Carlos Furche, Mexican agricultural economist at FAO, Salomón Salcedo, and others analyse past production and current international quinoa demand. They include the implications of recent price fluctuations on quinoa's international expansion. Peru and Bolivia, still the world's two largest quinoa producers, are developing new links with importers, but new producer countries are also emerging, including the United States of America, Canada, France, China and Morocco. These countries will compete with traditional exporter countries and the small- and medium-scale producers who live there. There is a clear risk in the international quinoa markets that new producer countries will corner the niche markets currently dominated by large Andean producers, especially in Bolivia and Peru, and also take over markets where Ecuador, Chile and Argentina are looking for a foothold. The chapter coordinated by Aurélie Carimentrand, economist at the *Université de Bordeaux* (University of Bordeaux) in France, analyses how the different quinoa certifications (organic, fair trade etc.) in the supply chain may add value to the product, increasing farmers' incomes and promoting local development.

The fifth part of this book contains chapters focused on the Andean countries where quinoa is grown. For each country, major quinoa specialists from the past 50 years review quinoa production system features and dynamics. These chapters are not thematic, but they provide a holistic vision of quinoa in each country, at various levels, taking into account the wide range of stakeholders involved in research, production, sale, and conservation. Quinoa's outlook in each of the five Andean countries is explored in the light of new stakeholders and new public policies aimed at developing quinoa crops. These chapters describe the success of quinoa production in fragile systems, and indicate the conditions necessary to maintain the sustainability of these agro-ecosystems.

The sixth and final part of this book comprises 11 chapters presenting examples of new countries or regions where quinoa is being produced – in Europe, Asia, Africa and North America. For example, Sven Jacobsen of the University of Copenhagen in Denmark describes Europe's initial forays into quinoa production and the crop's subsequent importance in the United Kingdom, the Netherlands and Denmark, within the framework of crop breeding programmes. Atul Barghava describes the agricultural potential of quinoa's biodiversity in the face of agricultural land salinization in India and Pakistan. Ouafae Benhabid of Morocco reviews the last 10 years of experimentation with quinoa in the mar-

ginal areas of the Atlas Mountains, and considers how quinoa might benefit small farmers. Larger-scale quinoa production programmes are also being developed with farmers who own large areas of land in the plains of Marrakech. The immense range of research projects being implemented in a variety of contexts is a reflection of the numerous objectives set by programmes and projects: drought resistance, tolerance to salinity, food security, the fight against poverty, export markets, family farming diversification, breeding varieties etc. While each situation presented relates to a specific development issue at various levels, the vital role of research networks in facilitating quinoa's sustainable global expansion remains a crosscutting theme. This means that research and the new knowledge it produces must be disseminated, or at least made accessible, to all. Regulations on phytogenetic resources have the power to promote or halt quinoa's current expansion, either building inclusivity or excluding certain stakeholders.

State of the Art of Quinoa in the World 2013 presents a snapshot of the current available knowledge, to enable us to reflect on potential short- and long-term scenarios, within which quinoa will continue to expand based on limited access to genetic resources in Andean countries, and restricted property rights to modern varieties developed in the North.

In the short term, the dominant trend of agricultural intensification focusing on genome advancements follows the industrial agricultural model that is driving us ever further away from sustainable food production and access to healthy foods. The *State of the Art of Quinoa in the World 2013* contributes to changing this scenario by forcing us to engage in dialogue with stakeholders and prevent quinoa's potential being lost in the face of conflicts over access to genetic resources and seeds. Rather, this book acts as a tool to develop joint innovations and share conservation costs. The full implications of quinoa's global expansion must be considered. Otherwise, both quinoa's biodiversity and the future of the Andean communities that depend on quinoa crops for local development in their regions will be threatened.

The international challenge of building an equitable long-term solution is tied to the geopolitics of quinoa. Today, new experimentation centres are opening in countries that previously did not even import quinoa. This leads to new competition on the global market, where small Andean producers will find that organic or fair trade certification is not enough in the face of competition from large-scale producers who, unlike them, have access to the financial capital necessary to invest in new forms of intensification. Against this backdrop, quinoa must be promoted not only as a crop, but also as an efficient and inclusive food and agricultural system to develop the most vulnerable sectors where South-South Cooperation has to play a central role.

This implies that the various stakeholders involved in quinoa's food and agricultural system must promote:

a) Monitoring of market behaviour, particularly the international markets, so as to predict supply and demand imbalances with a negative impact on prices;

b) Public policies that build the conditions necessary for fair trade and equitable distribution, to benefit farmers and local organizations;

c) Public policies that promote sustainable quinoa production, and agro-ecosystems where it is produced, while strengthening the food system;

d) Social inclusion policies that ensure quinoa contributes to territorial development and promotes the recognition of other Andean grains;

e) Monitoring of the expansion of growing areas at international level, and its impact on biodiversity depending on the agricultural models chosen;

f) Creation and implementation of international and national instruments for the protection, sustainable use and exchange of quinoa germplasm and seeds;

g) Strengthening of research networks to continue generating and sharing information on quinoa, making research available in the local languages of the quinoa-growing areas.

It is hoped that this book serves as a tool to foster the development of inclusive, respectful, responsible and ethical quinoa programmes and projects in the world, making a real difference in the fight against hunger and poverty, while recognizing and valuing the traditional knowledge and practices of indigenous peoples in the Andean region, who have maintained and preserved quinoa's biodiversity for generations.